

## MARS SURFACE GAS CHROMATOGRAPH MASS SPECTROMETER

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A Mars surface lander Gas Chromatograph Mass Spectrometer (GCMS) is described to measure the chemical composition of abundant and trace volatile species and isotope ratios for noble gases and other elements. These measurements are relevant to the study of atmospheric evolution and past climatic conditions. A Micromission plan is under study where a surface package including a miniaturized GCMS would be delivered to the surface by a solar heated hot air balloon based system. The balloon system would be deployed about 8 km above the surface of Mars, wherein it would rapidly fill with Martian atmosphere and be heated quickly by the sun. The combined buoyancy and parachuting effects of the solar balloon result in a surface package impact of about 5 m/sec. After delivery of the package to the surface, the balloon would ascend to about 4 km altitude, with imaging and magnetometry data being taken for the remainder of the daylight hours as the balloon is blown with the Martian winds. Total atmospheric entry mass of this mission is estimated to be approximately 50 kg, and it can fit as an Ariane 5 piggyback payload.

The GCMS would obtain samples directly from the atmosphere at the surface and also from gases evolved from solid phase material collected from well below the surface with a Sample Acquisition and Transport Mechanism (SATM). A primary objective of the Viking GCMS experiment was to search for organic molecules that could provide evidence of past life on Mars. Although no organic molecules were identified by the Viking GCMS, its measurements of the nitrogen, argon, and xenon isotope ratios, and of the total abundance of noble gases such as argon relative to the mass of the planet provide evidence for substantial differences in the evolutionary history of the atmospheres of Mars and Earth. The Viking GCMS was not optimized for the latter measurements and a more rigorous test of models of atmospheric evolution, can be made with higher precision isotope measurements for the noble gases and common elements such as O, C, N, and H. These ratios are required in different molecular species, for example, the O isotopes in both CO<sub>2</sub> and H<sub>2</sub>O. The Viking search for organic molecules sampled solid phase materials from the highly oxidized surface layer where it is now evident that organic molecules would not survive over extended time periods. The experiment envisioned in the Mars Micromission described would obtain samples from a much greater depth of up to one meter below the surface, and would search for organic molecules trapped in ancient stratified layers well below the oxidized surface.

The solar powered balloon system has been described (Jones et al., Proc. Mars Micromission Workshop, JPL, 1998). High altitude deployment and operation has been recently demonstrated in the Earth's atmosphere in tests carried out by JPL. The GCMS would operate for up to several hours on the surface. The landed package would use battery power and transmit data to an orbiting relay spacecraft. The GCMS would be a greatly simplified version of the instrument (Niemann et al., ESA-SP 1177, 85, 1998) developed for the Cassini Huygens Probe of Titan's atmosphere. The sample collection system would be similar to that developed for the Champollion cometary lander experiment to deliver comet nucleus material to a microscope camera and a GCMS. SATM has demonstrated in recently completed tests the ability to penetrate very hard materials and even material from the interior of certain rock types could be obtained should these happen to be located beneath the sampling system. A lightweight package to measure atmospheric winds and temperatures would be included on the lander.

The scientific investigation based on the measurement system described would address the following 4 areas:

- (1) the molecular and isotopic composition of the well mixed atmosphere
- (2) the characteristics of the atmosphere/surface exchange of gas that occurs on a diurnal as well as a seasonal cycle
- (3) the nature of the subsurface volatiles in the Martian regolith
- (4) the search for organic material at depth up to one meter or more below the surface.

The composition and isotope studies would focus on key tracers of atmospheric loss to space and solid phase reservoirs. Key measurement goals would be the  $^{36}\text{Ar}/^{38}\text{Ar}$  ratio that was not well constrained by the Viking measurements and measurements of the krypton and xenon abundance and isotopic distributions. As demonstrated using data obtained in the atmosphere of Jupiter from the mass spectrometer on the Galileo Probe (Niemann et al., Science 272, 781, 1996) even subparts per billion mixing ratios of a heavy noble gas can be detected with good counting statistics using a simple gas enrichment system. These studies would allow a comparison of the present Martian atmosphere with the trapped samples of gas from the SNC meteorites and future samples returned from Mars. It is possible that samples may be returned that contain ancient samples of a substantially different atmosphere. Increased accuracy would be provided by these measurements of the isotope ratios for the common elements C, N, O, and H in different molecules.

Atmosphere surface exchange driven by the large diurnal surface temperature variations could be studied over 1 or more such cycles by the experiment proposed by measuring day/night composition differences. It is anticipated, however, that the lifetime of the lander experiments powered by batteries could not exceed several days.

The substantial landed mass allowed by the Micromission opportunity would enable subsurface sampling at considerably greater depth than is possible with small rovers of the Pathfinder class. The SATM technology is mature based on extensive development carried out for the Champollion DS4 Mission. Small samples (~ 0.1 cc) collected from depths of up to 1 meter below the surface would be returned to the oven subsystem of the GCMS where thermal processing to several hundred degrees centigrade would release organic molecules for GCMS analysis. In addition, a controlled temperature ramp with simultaneous monitoring of evolved gases ( $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{SO}_2$  etc.) would provide substantial information on the mineralogy of the sample.

In conclusion, insitu instruments on upcoming NASA missions working in concert with remote sensing measurement techniques have the potential to provide a more detailed investigation of mineralogy and the extent of simple volatiles such as  $\text{CO}_2$  and  $\text{H}_2\text{O}$  in surface and subsurface solid phase materials. Within the context of subsequent mission opportunities such as those provided by the Ariane 5 piggyback payload based Micromissions, it is essential to implement an even broader chemical analysis and to enable a significant extension of previous isotope measurements. Such a development would enhance the presently very active study of questions of atmospheric evolution and loss and past climatic conditions. The method selected to implement this program can be based on well-established mass spectrometry techniques. Sampled gas is chemically and physically processed to separate the gas mixture into components using gas chromatograph and related enrichment techniques. This allows trace species to be identified and reveals isotopic distributions in many cases with improved precision. Samples of interest, such as organic molecules, may lie deep below the highly oxidized surface layer and the

suggested program includes enhanced sampling techniques to measure volatiles preserved in solid phase material deep below the surface as well as gas from the well mixed atmosphere.